WATER WELL

PUMP TEST REPORT

FOR

ROMALDO COMMUNITY WATER COMPANY

WELL NO. 2

5587 West Camino Cielo
SANTA BARBARA, CALIFORNIA

APN 153 – 100 - 013

prepared by

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13 JULY 2017

ORGANIZATION

TEST FOR:	Romaldo Community Water Company 5587 West Camino Cielo Santa Barbara CA 93105 805-886-1850
WELL SITE	San Marcos Pass APN 153-100-013 Section 21, T5N, R28W SB B&M Santa Barbara CA 93105 Santa Barbara County
WELL LOCATION	34° 30.1319' N 119° 49.1115' W
WELL DRILLING	DCA Drilling & Construction, Inc. 11438 Sumac Lane Camarillo, CA 93012 805-491-2926 DCA DRILLING@GMAIL.COM
GEOPHYSICAL LOGGING	Pacific Surveys 4456 Via Saint Ambrose Claremont, CA 91711 800-919-7555
PUMP TESTING	Cascade Well and Pump Co. 1200 Via Regina Santa Barbara CA, 93111 805-965-7246
GEOLOGIST	William A. Anikouchine, PhD California Certified Engineering Geologist No. 1584 1636 Hillcrest Road Santa Barbara CA, 93103 805-962-4234

DEFINITION OF SOME TERMS USED IN THIS WATER WELL REPORT

SYMBOL	TERM	UNIT	DESCRIPTION
T	Transmissibility	gpd/ft	Flow of water through a section of aquifer 1 ft thick under the influence of a 100% hydraulic gradient.
i	Hydraulic Gradient	%	Downward slope of water surface or surface of equal head (pressure).
h	Hydrostatic Head	ft	Elevation to which water would rise if not confined.
Q/s	Specific Capacity	gpm/ft	Well yield per unit drawdown.
s	Drawdown	ft	Amount water level lowers in the well during pumping.
S	Coefficient of Storage		Volume of water removed from an aquifer per unit change in head in a unit cross-s
K	Hydraulic Conductivity	gpd/ft^2	Capability of an aquifer to permit the passage of water.
n	Porosity	%	Pore volume/volume of aquifer.
	Specific Yield	%	Drained water volume/volume of aquifer.
	Static Level	ft	Depth to water before pumping starts.
	Pumping Level	ft	Depth to water during pumping.
s'	Residual Drawdown	ft	Residual Drawdown
	Recovery	ft	Rise of water in the well after pumping stops.
t/t'	Test Times Ratio		Time since drawdown started/time since recovery started.
E	Efficiency	%	Ratio of Specific Capacity to Transmissibility.
R	Radius of Influence	ft	Distance from well to limit of the Cone of Depression.
	Cone of Depression		Logarithmic drawdown surface surrounding a pumped well.
	Water Table Aquifer		An aquifer having an unconfined water table.
	Piezometric Surface		Surface of equal Hydrostatic Head in an artesian well.
	Artesian Aquifer		An aquifer having an upper confining impermeable layer (aquiclude).

SUMMARY OF RESULTS

WELL PERMIT	1803 issued 14 February 2017
WELL DEPTH	710 ft (completed to 697 ft)
COMPLETED DRILLING DATE	22 May 2017
WELL COMPLETED DATE	5 June 2017
STEP DRAWDOWN TEST	27 June 2017
24-HR DRAWDOWN TEST	28 June 2017
RECOVERY, 1-HR TEST	29 June 2017

24-HOUR PUMP TEST RESULTS

Static Water Level:	244 ft
Apparent Specific Capacity:	5.82 gallons per minute per foot of drawdown after 24 hrs.
Transmissibility:	3654 gallons per day per foot of aquifer.
Tested Pumping Rate:	54 gpm.

WATER QUALITY ANALYSIS RESULTS

Electrical Conductance at 25°	591 µmhos/cm
Total Dissolved Solids	420 mg/l
Total Hardness	243 mg/l as $CaCO_3$
Sodium	26 mg/l
Chloride	22 mg/l
Calcium	71 mg/l
Sulfate	97 mg/l
Iron	130 µmg/l
Manganese	80 µmg/l

The well water meets drinking water standards set by the Santa Barbara County Health Services Department except for a slightly elevated value for manganese. This poses no health hazard. The water is suitable for drinking or for any other domestic purposes.

WATER WELL REPORT

INTRODUCTION

The following is a description of the testing of a water well located off West Camino Cielo in Santa Barbara County, California. The well site is off Camino de Romaldo. The location of the well is shown on the map in Figure 1. The elevation of the surface at the well site is 2052 ft MSL. The construction of the well and estimates of its productivity are presented in this report. The Santa Barbara County Health Services Permit Number 1803 was issued for the well on 14 February 2017. The well was drilled by DCA Drilling and Construction Co. from 12 May 2017 to 22 May 2017. Their Well Completion Report is not available for appending to this report so well specifications given here are anecdotal.

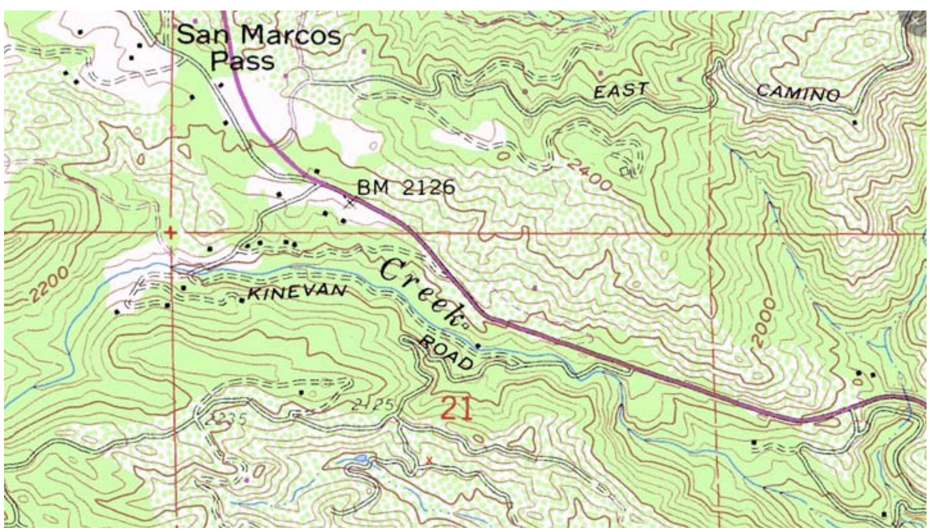

Figure 1. Part of the USGS San Marcos Pass topographic map showing the vicinity of the Romaldo #2 water well site. The location of the subject well is shown by the red X near the center bottom part of the map. The scale is approximately 1:10,000.

LOCAL GEOLOGY

The geology of the region around the well site is shown in Figure 2. The surface stratum in the vicinity of the well is sandstone of the "Coldwater" formation. The "Coldwater" formation consists of siltstone and shale with interbedded sandstone strata from about 3 ft to over 30 ft thick. The formation dips southward about 10° and strikes N 85° W. The well site is on the S flank of the Brushy Peak anticline. The axis of the anticline is about 600 ft N of the well site. The terrain at the well site is marked by a prominent bluff formed by a major vertical joint striking E-W cut by lesser joints trending normal to it.

GEOLOGY OF THE WELL

The well bore spudded into colluvium about 10 ft thick. The material under the colluvium appears to be over 710 ft of alternating sandstone and shale of the Eocene "Coldwater" formation. These strata were penetrated to the bottom of the borehole at a depth of 710 ft. The diameter of the borehole is nominally 10 in from 0 to 710 ft.

A lithologic log was prepared by the writer from available drill cuttings. Equal volume sub-samples were washed through a 64 micron sieve to remove fine material, and then examined under a 60x binocular microscope. The findings were augmented with observations of the electric log of the well. The lithologic log is as follows:

Depth, ft	Lithology
0 - 10	Colluvium, reddish brown, sandy loam. Observed during tremie re-drill.
10 - 50	Colluvium, gray to dark gray, sandy. Observed during tremie re-drill.
0 - 110	No samples taken by driller.
110 - 120	Sandstone, gray-buff, fine-grained, well-sorted, 70% gray angular quartz, 30% iron oxide-stained quartz, angular, occasional rock fragments, muscovite mica.
120 - 200	Sandstone, ochre to red-brown, fine-grained, well-sorted, 50% gray quartz, 50% iron oxide-stained, angular, ~1% muscovite mica. First water at 155 ft.
200 - 250	Sandstone, gray, fine-grained, well-sorted, 50% gray angular quartz, 47% iron oxide-stained angular quartz, ~1% muscovite mica, 1 to 2% 5 mm charcoal fragments. Well-cemented and hard at 290 – 300. Long-term water table at 200 ft.
250 - 300	Sandstone, gray, medium-grained, 50% gray quartz, 46% opaque limonitic quartz, 1% muscovite mica, 1% dark rock fragments, 2%

	5 mm charcoal fragments. Well cemented sandstone at 270' – 280'
300 - 310	Siltstone, dark gray, soft, trace of pyrite.
310 - 340	No samples taken by driller.
340 - 430	Shale, dark gray, silty, moderately compacted. Fine-grained, well-cemented gray sandstone at 430 ft.
430 - 480	Sandstone, gray, medium-grained, well-sorted, 80% gray quartz, 20% iron oxide-stained quartz, occasional dark rock fragments, muscovite mica. Weakly-cemented sub-angular sandstone at 470' – 480'. No sample taken by driller for 440 to 450 ft interval.
480 - 490	Shale, dark gray, compact.
490 - 510	Sandstone, gray, medium-grained, angular gray quartz, < 1% dark rock fragments,
510 - 570	Shale, dark gray, silty, compact. Medium-grained, well-cemented sandstone interbed at 550 ft.
570 - 630	Sandstone, gray, medium-grained, Weakly-cemented angular quartz sandstone at 590' – 600'. Dark gray shale interbeds at 600 to 610 ft and at 620 to 630 ft.
630 - 670	Shale, dark gray, silty, compact. Gray medium-grained sandstone at 660 to 670 ft.
670 - 710	Shale, dark gray, silty, very compact, very fine-grained gray sandstone micro- lamina are visible on large fragments. Fracture zone.
TD	

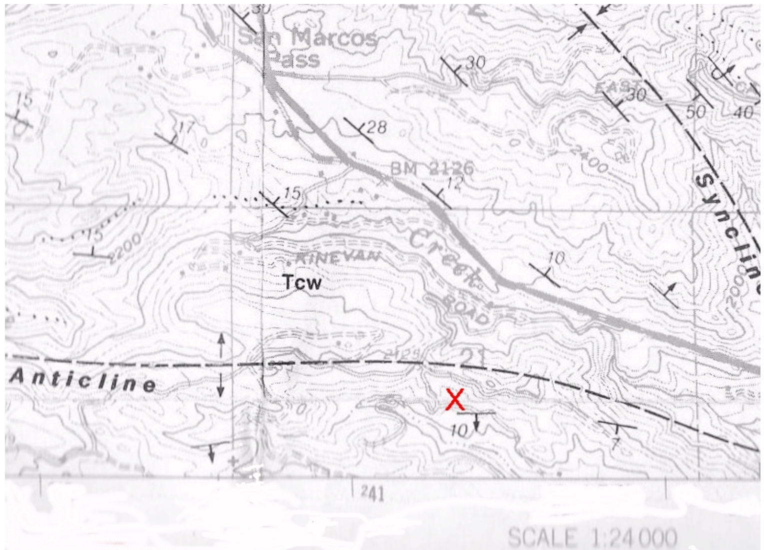

Figure 2. Geologic map of the region around the well site which is marked with the red X. The anticline is the Brushy Pek anticline. Tcw epresents the "Coldwater" sandstone outcrop. Map from Dibblee (1987).

WELL CONSTRUCTION

The well borehole was drilled using a down-the-hole hammer style of drill, a style more appropriate for drilling hard crystalline rocks such as basalt, quartzite, granite, and limestone rather than sandstone and shale (Driscoll 1986). No collars or stabilizers were used.

Drilling the borehole was initiated on 12 May 2017. The borehole was drilled on air to a nominal diameter of 10 inches. The drill string became stuck on a dogleg at 150 ft (see Figure 5). A larger compressor was brought in and drilling continued until a dogleg at 310 ft. The borehole communicated with the original Romaldo well located 40 ft away to the east causing air circulation to be lost at 310 ft. A 10-inch ID steel conductor pipe was set to a depth of 60 ft and the hole filled with cement. The hole was re-drilled through the cement and to a depth of 710 ft by May 22 2017. An E-Log and Deviation Log were run in the hole immediately.

Certa-lock PVC SDR 17 6-inch slotted casing was set on 23 May 2017. The casing had 672 slots 0.034” x 2.75’ per ft. Slot area was 59 sq in per ft. The casing became stuck on a dogleg at 350 ft. The casing was pulled out of the hole and the hole re-drilled to 700 ft. Casing could then be set to 700 ft on May 24.

The filter pack material for filling the annulus of the well was selected to be #12 Silica Sand by the driller. Its specifications were examined following the method of Johnson (1963). The slot size and the filter pack characteristics were determined from grain size analyses of the aquifer and a sample of the filter material. The results of the analyses are shown in Figure 3.

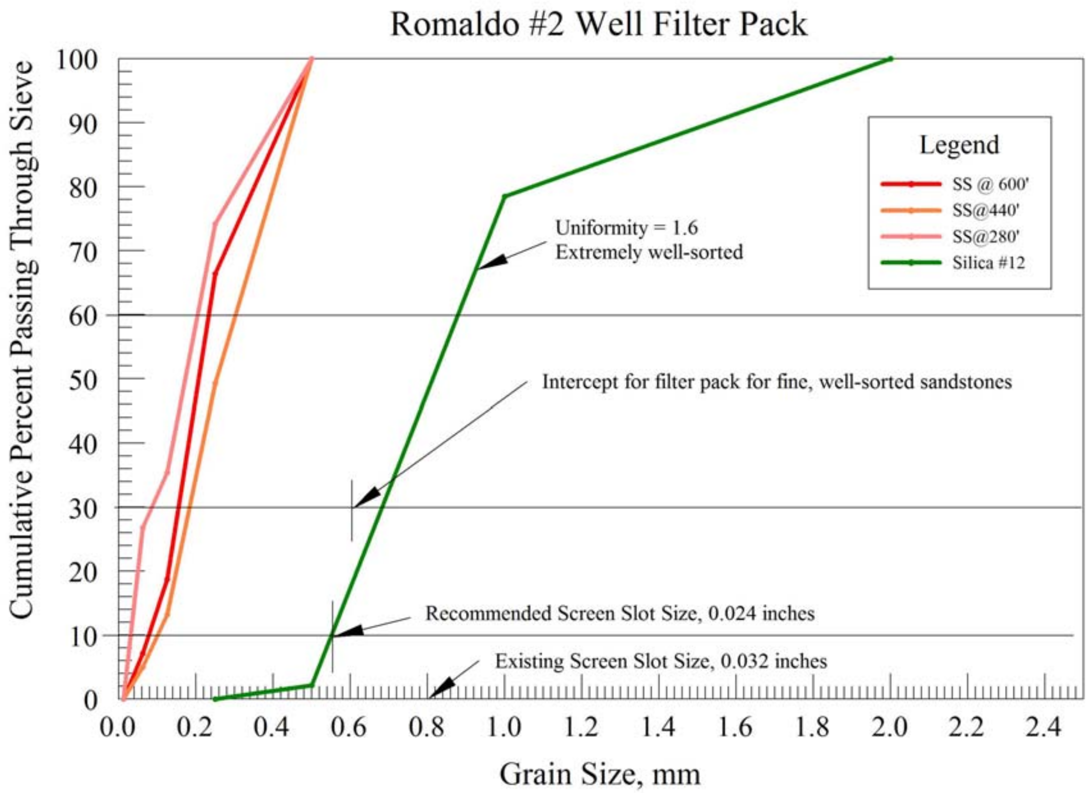

Figure 3. Grain size analyses of sandstone beds of the "Coldwater" formation and the installed filter pack. Filter pack and screen design considerations after Johnson 1963 are shown.

The Silica #12 filter material is the closest fit to the specifications available locally. The installed slot size (0.032 inches) exceeds the D_{10} of the filter pack material. A one-gallon sample of water pumped from the well was allowed to settle for several hours to determine if the well produced sand. No settled sand was observed.

DEVIATION

A deviation survey was performed with the electrical logging of the well on 22 May 2017. Salient results of the survey are shown in Figure 4 and Figure 5. The map in Figure 4 shows that the borehole of the well deviates a total of 22 ft to the N at total depth. The limit of acceptable deviation set forth in the Handbook of Ground Water Development (Roscoe Moss, 1990) cited in DePonty et al (2013) stipulates a limit of 6 inches of deviation per 100 ft of well depth or, for a 700 ft well, 42 inches, indicating that the well bore is grossly misaligned.

A less stringent limit proposed by the U.S Environmental Protection Administration is 1° deviation per 50 ft of well depth. Even with such a relaxed requirement the lower 250 ft of the well bore exceeds this limit. These measurements indicate that the well was drilled not plumb, but straight over two segments below 350 ft.

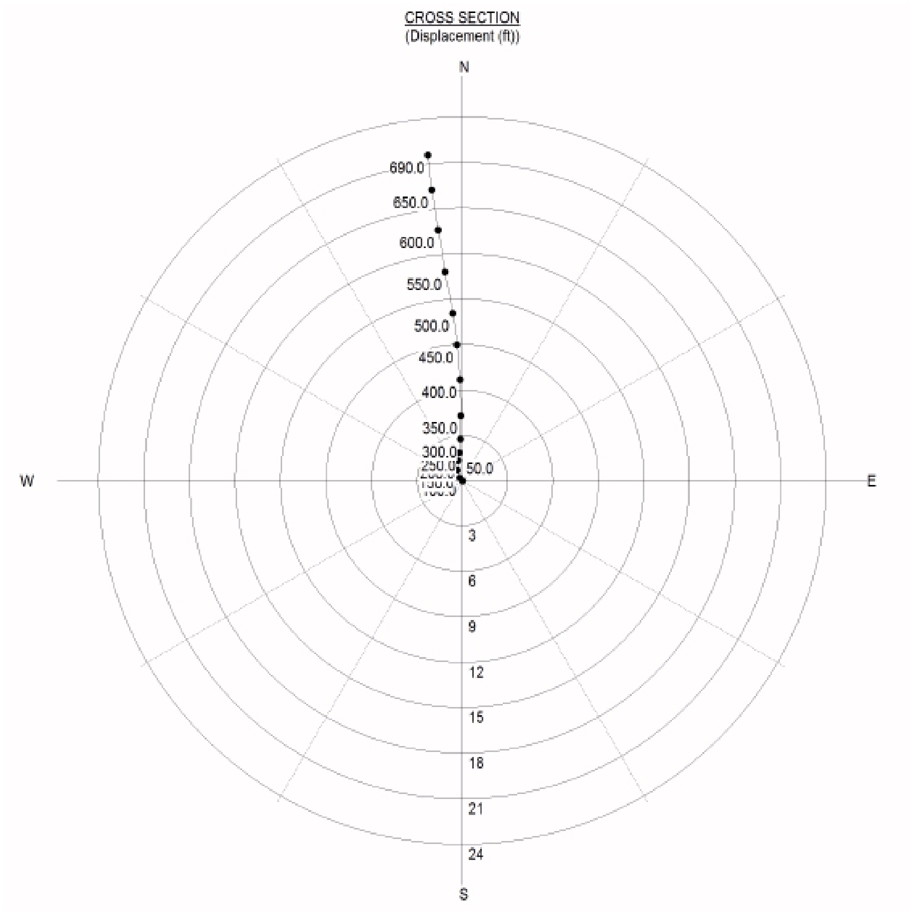

Figure 4. Map view of the deflections in the Romaldo #2 well bore (curved line with dots). The azimuths are referenced to magnetic north. The numbers on the curved line are the measured depths in feet at the point. The numbers along the S bearing line are the lateral displacements from the vertical in feet. The deviation of the well is 21.6 feet to the N at the bottom of the hole (697 feet).

Figure 5 shows that there are several variations in alignment, called "doglegs" in the well bore. The severest doglegs range from about 8°/100 ft to 10 °/100 ft. Problems installing casing and screen and introducing a filter pack in the well are to be anticipated.

The maximum allowable dogleg severity cited in the literature ranges from 2.5°/100 ft used for wells in the Gulf of Mexico to 3.0°/100 ft used for wells in the North Sea. These values of maximum dogleg severity are those that would prevent drilling pipe failure from abrasion and cyclical flexing. Values from 4°/100 ft to 6°/100 ft are cited as the range of average values used in the industry.

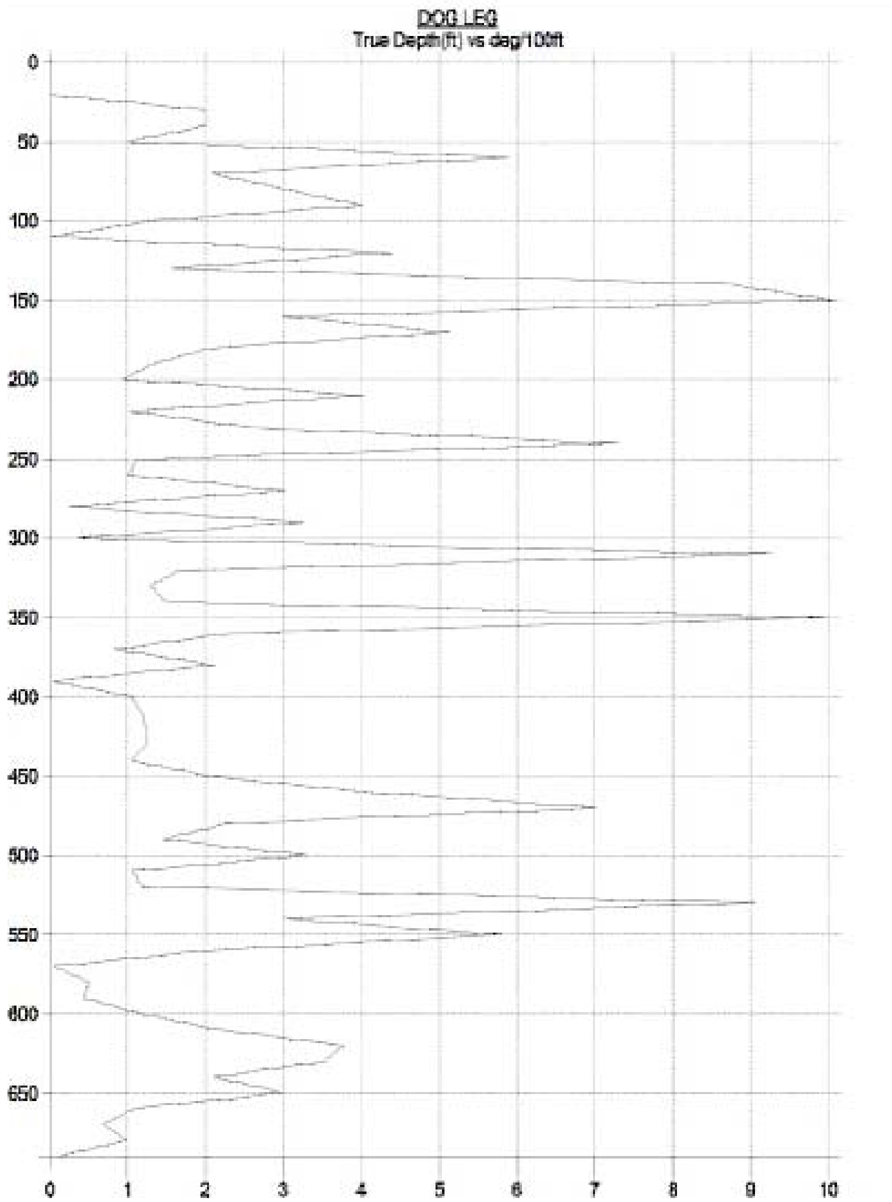

Figure 5. Dogleg Severity by the minimum curvature method. Values are calculated every 10 ft.

The severe deviation of the well bore required that centralizers be installed every 20 ft on the lower 500 ft of the casing. This was to prevent the casing from resting on the bottom side of the well bore and impeding the passage of water through the slots as well as preventing the uniform introduction of filter material. The construction of the well is shown by the schematic drawing in Figure 6.

SANITARY SEAL

The steel conductor pipe could not be extracted from the well bore. Apparently it had been cemented to the side of the borehole during the cement and re-drill operation. To obtain an acceptable sanitary seal for the well it was necessary to bore into the annulus outside the steel pipe tangent to the west side of the well bore. A 6-in hole was drilled to a depth of 50 ft to permit a tremie to introduce the cement slurry from the bottom of the 6-in hole up into the annulus between the steel pipe and the 12" bore hole. After this annulus was filled with slurry, more slurry was dropped into the annulus between the steel pipe and the casing. Upon completion of this operation a 10' x 10' x 2", steel-reinforced well pad was poured and allowed to set. Shortly afterward, a 2' x 2' x 1' step was poured around the steel pipe protruding though the pad.

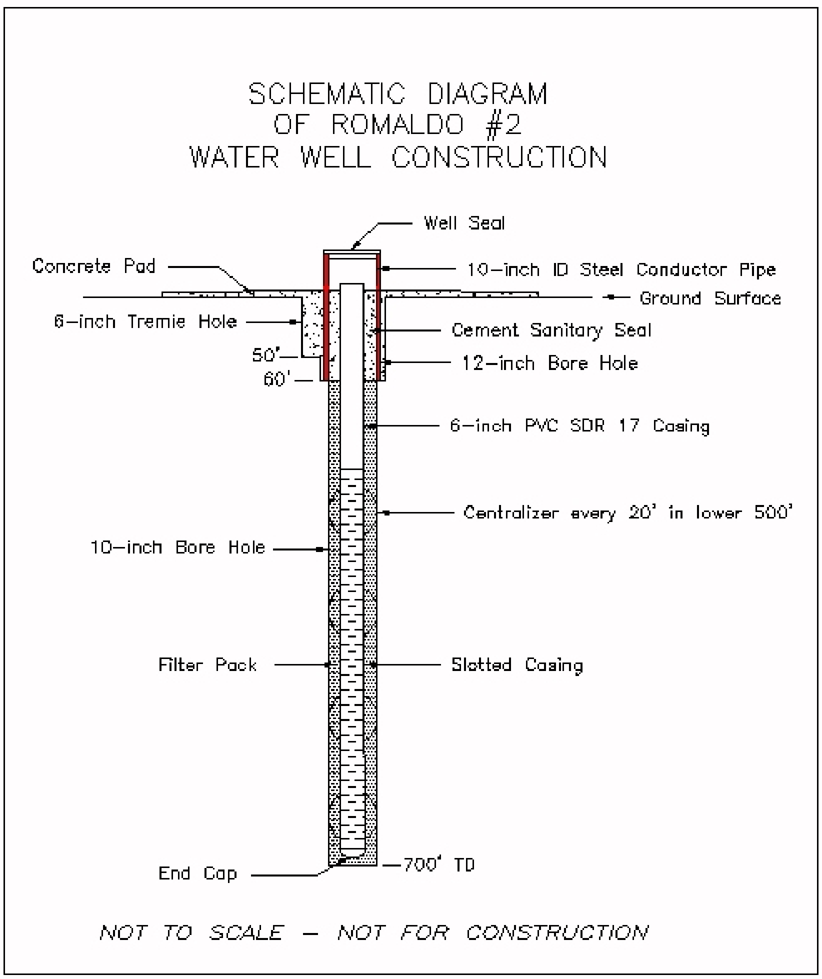

Figure 6. Drawing illustrating the construction of the Romaldo #2 water well.

TEST PUMPING

The completed well was pump-tested to determine its hydraulic characteristics and the hydraulic characteristics of the aquifer serving the well. The results of the initial testing were used to determine if the well could provide sufficient water for the client's needs and to aid in the selection of a suitable pump.

The well was fitted with a test pump and an air line was placed on the drop pipe for the purpose of measuring the depth to the water surface during the tests. The air line was charged by a nitrogen bottle and the pressure in the air line was measured on a gauge having a 2 in face and 2 psi gradations.

The testing regimen included step drawdown test followed the next day by a formal drawdown and recovery test. The well was pumped at 54 gpm for 24 hours on 28-29 June 2017. At the conclusion of the drawdown test a 1-hour recovery test was performed. Discrete water level measurements were recorded manually. The measurements are presented at the end of this report.

The step drawdown test was performed to determine the appropriate pumping rate to be used for the drawdown test. The well was pumped for an hour at successive rates of 20, 30, 40, 50, and 58 gpm. The drawdown at each step was plotted against the corresponding pumping rate on Figure 7.

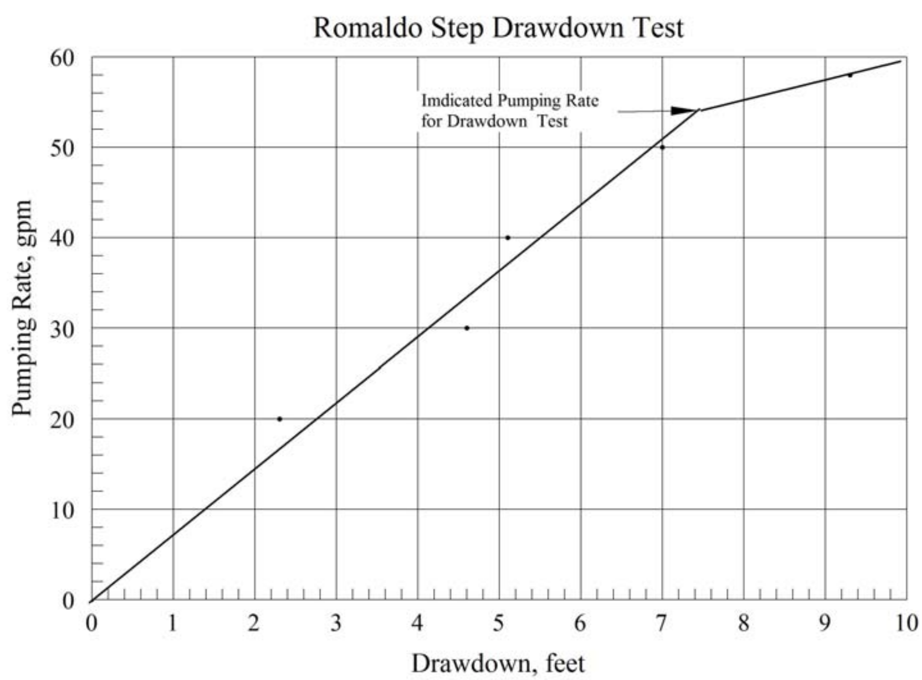

Figure 7. Plot of step drawdown test result. The break in the curve at 54 gpm indicates onset of turbulent flow, hence the maximum suitable pumping rate for the drawdown test.

The figure indicates that the appropriate pumping rate for the drawdown test was 54 gpm. This is the maximum rate of pumping that does not induce excessive turbulent flow into the well.

WELL EFFICIENCY

The efficiency of a water well is derived by comparing the specific capacity under theoretical laminar flow through the aquifer, the disturbed zone around the well bore, the filter pack, and the screen to the actual specific capacity measured during a pump test. Turbulence in all of the zones causes the drawdown to be greater than that when only laminar flow occurs.

The equation for calculating the well efficiency at several rates of pumping during a step-drawdown test is

$$E_w = 100BQ/s$$

where: B is the coefficient of aquifer loss caused mainly by laminar flow,
Q is the rate of flow from the well, and
s is the total drawdown at each step.

The values of well efficiency obtained from the step drawdown test are given in the following table.

Test Data		Well Efficiency
Q	s	$9Q/s$
58	9.3	56.1
50	7	64.3
40	5.2	69.2
30	4.6	58.7 (error?)
20	2.5	78.3

The table shows that the well becomes inefficient when pumped at rates greater than 40 gpm. The pumping rate recommended to secure maximum efficiency is 20 gpm. The use of a variable frequency device pump control should be set to operate ordinarily at that value or a smaller one.

DRAWDOWN PUMP TEST

The static level of the water in the well was 239.8 ft at the start of the drawdown test. The data from the initial 10 minutes of the pump test were ignored because the assumptions of the Jacobs modification of the Theis equation (the theoretical basis of the pump test) are not valid in that time range.

BASIS FOR ANALYSIS OF PUMP TEST DATA

When pumped at a constant rate, a water well that penetrates porous and permeable earth materials exhibits a drawdown that varies with time according to classical equations of dynamics (variations of Poisson's equation). The equations describe an initial transient (non-linear variation with time) behavior that relaxes toward a steady (time-invariant) state with the passage of time. In the literature of groundwater hydrology transient behavior is called non-equilibrium behavior and the steady state is called equilibrium behavior.

It is important to realize that all wells behave in this manner. Differences between wells are noted because in some wells the transient phase of the drawdown relaxes rapidly (in a few seconds to a few minutes) but in others the transient phase persists for days. The behavior of a well is governed by the relaxation coefficient in the equation describing the aquifer. The relaxation coefficient is determined by the ratio of the storage coefficient (or specific capacity) of the aquifer to its transmissibility. In general, the larger the transmissibility, the shorter the duration of the transient phase.

Well performance during constant pumping is further complicated because the geologic setting of an aquifer creates unique boundary conditions and distributions of sources and sinks that render the temporal behavior of the drawdown rather complex. This complexity causes the interpretation of pump test data to require an understanding of the geohydrology of the region around the well.

In terms of geohydrology, an aquifer that extends to the surface is a water table (or unconfined) aquifer. Areas of nearby recharge of groundwater constitute sources. Barriers that truncate the aquifer (such as faults and stratigraphic facies changes) act as virtual sinks.

The classical method of designing a pump test is to seek the pumping rate that "stabilizes" the well at a particular drawdown level. However not all wells can be made to exhibit this behavior. "Stabilization" of a well is a concept that implies that water is supplied to a well at the rate that it is being withdrawn. "Stabilization" occurs when the cone of depression of the well intercepts a source of recharge such as a body of surface water (river or lake) or a region of higher transmissibility.

Wells in alluvial terranes exhibit equilibrium behavior because of the generally high transmissibilities of the unconsolidated nature of the aquifer materials there. Under equilibrium conditions the pumping level in the well pumped well beyond a sufficient elapsed duration appears not to change. Actually an asymptotic change occurs indefinitely but the pump test equipment often lacks the resolution necessary to detect it.

The design of the pump test and the interpretation of the results are directed toward establishing that one can reasonably conclude that the water supply from the well is in fact adequate. This is done by determining the trend of the drawdown vs log time function for the well and projecting the trend for some arbitrarily long interval of time (in our practice, 1 year).

The results of the 24-hour drawdown test and the recovery test are appended to this report and are presented on the graph in Figure 8:

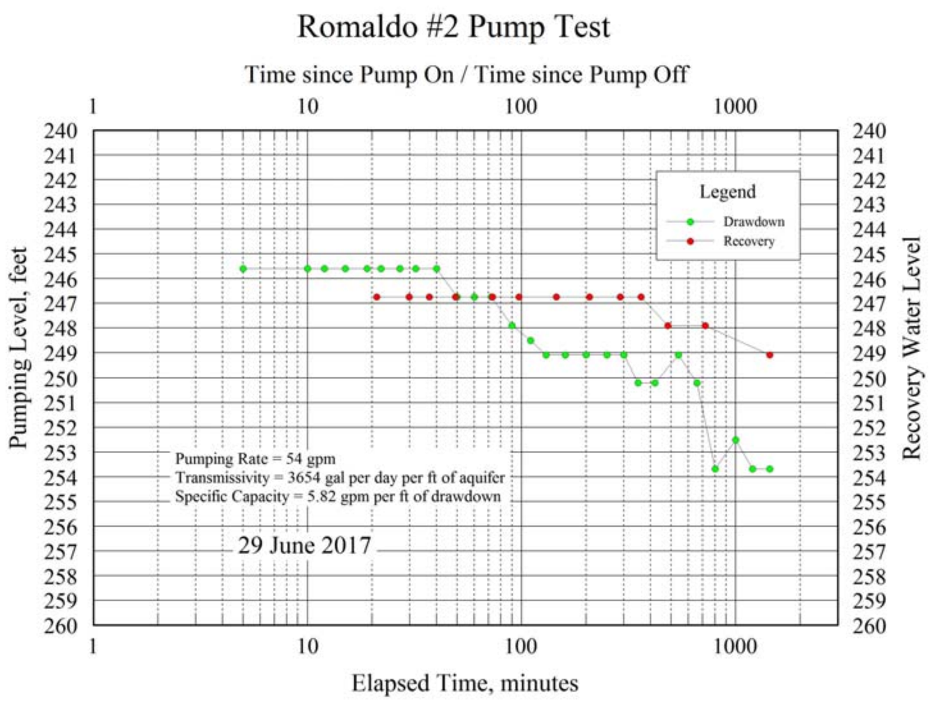

Figure 8. Results of the 24-hr pump test of the Romaldo #2 well. The recovery of the well after the drawdown test is also shown. The recovery axes are to the right and at the top of the graph.

ANALYSIS OF PUMP TEST RESULTS

The subject well appears to be of a water table (unconfined) equilibrium type. Its transient (non-equilibrium) phase decayed a few minutes after the start of the test. The lack of a pronounced sigmoidal character in the time-drawdown signature suggests that leakage into the aquifer was negligible. Dewatering of the casing was not significant, suggesting that the well was not being over-pumped during the test.

The drawdown remained constant for the first 40 min and increased at a constant rate for the remainder of the test. The drawdown indicated a transmissibility of about 3654 gpd/ft of aquifer.

At the end of the drawdown test, the pump was stopped and a recovery test (time vs residual drawdown) was made. Recovery was allowed to proceed for 1 hour. The residual drawdown at the end of the recovery test was 2.35 ft. The transmissibility of the aquifer indicated by the recovery data was 11880 gpd/ft of aquifer. This greater value indicates that the hydraulic conductivity was improved during the drawdown test, probably by flushing of fines from near the well bore. This value represents the transmissibility of the sandstone aquifers and the fractured material at the bottom of the well. A projection to a unity t/t' ratio indicated that groundwater was not mined during the pumping tests.

The apparent specific capacity of the well was calculated to be 5.819 gpm/ft after 24 hrs. This is a value that is typical of wells in highly permeable aquifers. A projection of the time-drawdown plot to a depth of 425 ft (depth of the pump) indicated that the theoretical maximum yield of the well is in excess of the rate used for the pump test.

The determination of the perennial yield of the well will require observing several years of performance under the duty cycle used with the new pump and pump depth. A regular program of pumpage and pumping level measurement is recommended for this purpose. A weekly log that notes the duty cycle (time pump turned on and time pump turned off) and the pumping rate should be kept for this purpose. In addition, periodic recording the pumping level and a running total of gallons delivered is recommended.

PUMP SELECTION

The pump tests were conducted after several years of sub-normal precipitation, so the drought-induced lowering of the regional piezometric surface in the subject well probably had occurred. Nonetheless a conservative choice of pumping level would be prudent. In consideration of this, a permanent pump should be set at a depth of 420 ft. The design static level should be taken to be 244 ft. A pump selected for service in the subject well needn't have a steep performance (head-capacity) curve inasmuch as the pumping level would vary little even during vigorous duty cycles.

The 24-hr drawdown and recovery tests indicate that the pumping level in the well would lower about 2 ft after a year of pumping at 20 gpm. Protracted pumping at 20 gpm would not bring the pumping level to the NPSHr of most pumps considering that the calculated NPSHa of the well is 210 ft.

System head calculations assumed a design flow of 20 GPM through 1 1/2 inch PVC plumbing. The calculations for an elevated tank were done assuming 522 ft of pipe rising 150 ft from the well head to the top of a storage tank. The calculations include the friction head loss from fittings and valves likely to be installed in the delivery pipeline. A discharge line pressure of 60 psi could be used to lift water to an elevation about 130 ft above the tanks if desired.

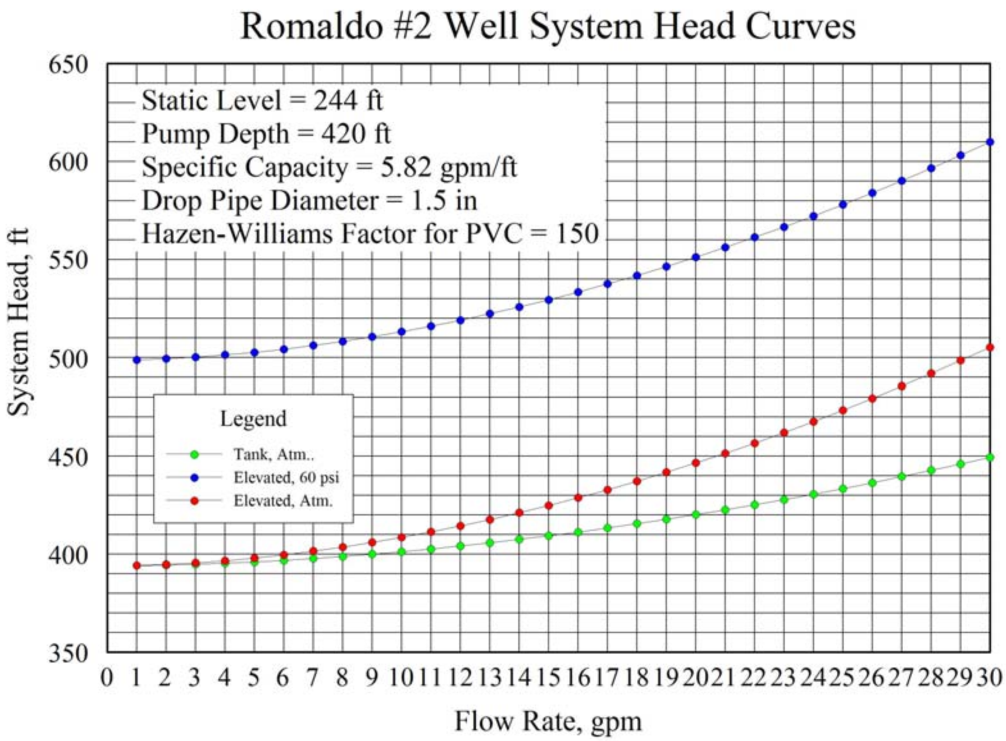

Figure 9. System head curves for three possible configurations of system plumbing. Tank, Atm. delivers into an existing tank. Elevated, Atm delivers into a tank 150 ft above the well head and 522 ft away. Elevated, 60 psi delivers into that elevated tank, but at a service pressure of 60 psi.

The system head curves in Figure 9 permit choosing a pump operating point for specific purposes. For filling the existing tank 50' away from the new well, the operating point is 411 ft head at 20 gpm. Discharge is against atmospheric pressure. For filling a new tank located on a hill 150 ft above the ground level at the well and 525 ft away, the operating point is 427 ft head at 20 gpm. If that discharge is to provide 60 psia service pressure, the operating point is 532 ft head at 20 gpm.

The operating point data do not include the friction effects of every likely fitting in the delivery pipe since a plumbing plan is not available. The Hazen-Williams friction coefficients for pipe friction were used in the system head calculations. That gives friction heads considerably higher than those obtained by the more common Darcy-Weisbach method, so the friction head numbers are conservative.

Because the borehole of the well is grossly deviated, the drop pipe for the pump must be fitted with centralizers to keep the pump and pipe from contacting the casing. A centralizer should be placed just above the pump to assure that the pump inlet is not restricted. Water must be allowed to approach the inlet from below so that it can pass by and cool the pump motor.

WATER SAMPLE ANALYSES

At the conclusion of the drawdown pump-test, a water sample was collected for chemical analysis. The water sample was taken from the well on 29 June 2017. The analyses were performed by the Fruit Growers Environmental Laboratory of Santa Paula, CA. The results of that water quality analysis are appended to this report.

The water quality for domestic purposes can be assessed by comparing the analysis data to the Maximum Contaminant Levels of the State of California Department of Health Services that are shown on the appended sheet.

The analysis results indicate that the water drawn from the well is suitable for domestic use without treatment. The level of manganese in the well water is slightly above maximum water quality levels for domestic water. This can be treated by using a greensand filter system, but it probably is not necessary. The water hardness is low for this region. It might not be necessary to soften the water for domestic use.

IRRIGATION WATER ANALYSIS

Interpretations of water analyses as related to crop growth should be made only after consideration of soil and plant conditions. In applying irrigation, it is necessary to have adequate drainage and it is good practice to apply enough water to leach out the salts accumulated from the previous irrigation. The more saline the irrigation water, the greater amount that should be applied per irrigation. The individual properties of the well water of concern for irrigation use are discussed below.

Total Sulfides (as hydrogen sulfide) Total sulfide represents the amount of dissolved hydrogen sulfide gas that would exist if all dissolved sulfide, hydrosulfide and various polysulfide ions dissolved in the water were to be converted to hydrogen sulfide. Sulfides are deadly to both aquatic plants and aquatic animals and create chronic odor problems if water from the well is used to fill an ornamental pond or aquaculture tanks. Sulfur precipitated from the oxidation of sulfide is not especially deleterious to plants; elemental sulfur is often used as a soil amendment. Sulfide in water fouls copper plumbing; in severe cases the plumbing eventually would have to be replaced.

Dissolved sulfides are readily detected at low levels by the rotten eggs smell of certain organic sulfur compounds that are associated with dissolved hydrogen sulfide gas. The odor was not detected, so it is probable that sulfide levels in the water are negligible. It does not seem necessary to analyze for the actual sulfides content of the well water to confirm the actual sulfide level.

pH (Acidity) The acidity of the water as indicated by the pH factor measured in the water sample was 7.5. This is just slightly alkaline but well within the range of values typical of groundwater in this region. No neutralization need be applied before direct application on plants. Aeration would shift the pH of the water toward neutrality during its use for irrigation.

Chloride ion (Cl^-) The chloride ion concentration in the water sample taken from the well during the pump was 22 mg/l. This ion is the most troublesome ion in irrigation water, but the value obtained from the well water indicate that no injury to sensitive plants could be expected if this water is used for irrigation.

Boron ion (B) Too little or too much (over 0.5 mg/l) of the essential nutrient boron is deleterious to certain higher plants. Citrus trees, avocados, walnuts and blackberry plants are particularly sensitive to elevated boron levels. The boron ion was not detected in the well water. Boron might need to be added to the water if it is used for irrigation. The boron tolerance of plants is given in the following list.

RELATIVE TOLERANCE OF CROP PLANTS TO BORON
(in order of increasing tolerance in each column)

SENSITIVE	SEMITOLERANT	TOLERANT
0.5 MG/L	1.0 MG/L	2.0 MG/L
Lemon	Lima Bean	Carrot
Grapefruit	Sweet Potato	Lettuce
Avocado	Bell Pepper	Cabbage
Orange	Tomato	Turnip
Blackberry	Pumpkin	Onion
Apricot	Corn	Alfalfa
Peach	Wheat	Garden Beet
Persimmon	Barley	Sugar Beet
Grape	Olive	Date Palm

SENSITIVE	SEMITOLERANT	TOLERANT
Plum	Cotton	Asparagus
English Walnut	Potato	
1.0 MG/L	2.0 MG/L	10 MG/L

Sulfate ion ($SO_4^{=}$) Sulfate ion is thought to be less toxic to plants than chloride ion in irrigation water. However in high concentration the sulfate ion can cause the precipitation of calcium sulfate which is not desirable. The sulfate levels in the well water was 97.0 mg/l. after the 24-hour pump test. This level is below the mean level for this region and it is probably below the level of calcium sulfate precipitation.

Specific Conductance in μmhos/cm. This is a measure of the salinity of the well water. Elevated values are deleterious because of the lack of salinity tolerance found in certain plants. Extremely low values (below 200 μmhos/cm) indicate a potential for reducing soil permeability. The value measured in the well water was 591 μmhos/cm. This value represents no salt hazard, but plants having no salt tolerance should not be irrigated with this water.

Potassium ion (K) Potassium in irrigation water tends to act like sodium in reducing the permeability of soil. On the other hand it is a necessary plant nutrient. The well water had an undetectable concentration of dissolved potassium ion. A balance must be maintained between the levels of potassium, phosphorous and nitrogen presented to plants. This is usually achieved by the application of suitably formulated commercial plant fertilizer therefore it is prudent to be mindful that the irrigation water might be providing no part of the plants' potassium requirement and so should be neglected in the formulation of the fertilizer. An excess of potassium ion in the soil is to be avoided.

Nitrate ion (NO_3^-) Nitrate too can reduce soil permeability if it is present in high concentration. It is a plant nutrient that is often limiting in a soil so modest levels of dissolved nitrate ion in irrigation water are beneficial. Nitrate was not detected in the well water. Testing irrigated soil for the current levels of potassium, phosphorous and nitrate is suggested to determine how additional fertilization should be formulated.

Magnesium ion (Mg) Magnesium is essential to normal plant growth and promotes good soil permeability and texture. The level of magnesium in the well water was 16 mg/l. The well water should be suitable for application to soil without any danger of impairment of soil permeability.

Calcium ion (Ca) Calcium ion is also essential for normal plant growth and it acts in concert with magnesium to promote good soil conditions. The level of dissolved calcium ion in the well water was 71 mg/l. Loss of soil permeability should not be an issue of concern.

Manganese ion (Mn) The manganese ion is essential for plant growth. When it is in short supply in soil it is applied as an additive to plant fertilizer. The level of manganese in the well water was 80. This indicates that the water contains considerable manganese and need not be added to fertilizer used on irrigated crops. Although the concentration of manganese in the well water exceeds the maximum permissible level slightly, no health hazard exists. Slight brown staining of dishware and porcelain might occur under some conditions.

Metal ions Most dissolved metals are necessary micronutrients for plants at low levels. Some of the metals such as copper, zinc, cadmium and selenium are toxic at relatively low levels however. Neither copper nor selenium were detected. Zinc was detected at a low level, 40 μg/L. No metal toxicity toward aquatic plants or aquatic animals is anticipated, but it might be necessary to add micronutrients (such as chelated metal species) to the irrigation water to assure that sufficient quantities are available to irrigated crops if soil levels indicate a deficiency of these elements.

Iron ion (Fe) Ferrous iron in water is deleterious to fish at elevated levels. Iron was detected to have a concentration of 130 μg/L in the well water. Although this is a low level, Iron might be a problem in maintaining fishes in a pond filled with the well water. The water would have to be kept well oxygenated because should the water allowed to become anoxic, the danger of ferrous iron poisoning of fish would exist.

WELL RELIABILITY

The reliability of a water well is evaluated by considering those factors that could lead to well failure. The geohydrology of the region, the quality of the construction of the well and the operation of the well are the general topics considered.

The materials intersected by the well bore consist of about 10 ft of colluvium overlying strata of the "Coldwater" formation. The sandstone strata within the "Coldwater" formation form the most productive aquifers in this well. The behavior of the subject well during the pump tests indicates that the aquifers serving the well are limited by lateral barriers at a distance that the cone of depression reached in 40 minutes. Although the sandstone strata forming the aquifer in the well have considerable lateral extent, the fractures intersected by the well bore would be of limited extent and exhibit barrier performance. Even after a barrier is reached, the well is quite productive and is characterized by large transmissibility values.

The construction of the well was not without problems, but these were overcome by judicious application of current technology. The well proved to be quite crooked such that centralizers had to be placed on each joint of casing. Even so, the casing became stuck and had to be withdrawn so the well bore could be re-drilled. After that, the casing could be installed to the total depth of the borehole. The well did not produce fine sand, silt or clay during the pump tests even though wells in sandy formations such as the "Coldwater" formation aquifer have a tendency to produce silt. Pumping the subject well at high yields would increase the tendency for sand production. It is advisable to pump the well at the minimum suitable rate. If sand production becomes a problem, install a sand trap in the delivery system at the well head.

Dry weather and drought-induced lowering of the water table is not likely to affect the capability of the well to supply water at the rate of 20 gpm. The pump in the well should be set at a depth of 420 ft. If the piezometric surface drops, the pump could be lowered by 240 ft before reaching the bottom of the well. A better practice would be to use the well at a minimum yield so that a reserve of water is always present in storage in the aquifer.

These factors suggest that the subject well should prove to be a useful source of water for use at yields of 20 gpm if care is taken to provide suitable intervals of recovery of the well between intervals of protracted withdrawal from the well. The life of the well can be estimated to be in excess of 60 years, based upon the life of the original Romaldo well located about 40 ft away. One could expect even greater lifetime were it not for the extreme deviation of the well bore.

Respectfully submitted,

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WELL PUMP TEST DATA

STEP DRAWDOWN

ROMALDO COMMUNITY WATER COMPANY

WELL #2

Step Drawdown Test

27 June 2017

FLOW GPM	WATER LEVEL FT	DRAWDOWN FT
20	242.1	2.3
30	244.4	4.6
40	244.9	5.1
50	246.8	7.0

58	249.1	9.3

24-HOUR DRAWDOWN & RECOVERY

ROMALDO COMMUNITY WATER COMPANY

WELL #2

TIME-DRAWDOWN TEST (24 hrs)

28 June 2017

TIME SINCE PUMP STARTED	PUMPING LEVEL	DISCHARGE
MIN	FT	GPM
0	244.4	54
5	245.6	54
10	245.6	54
12	245.6	54
15	245.6	54
19	245.6	54
22	245.6	54
32	245.6	54

TIME SINCE PUMP STARTED	PUMPING LEVEL	DISCHARGE
MIN	FT	GPM
40	245.6	54
50	246.75	54
60	246.75	54
72	246.75	54
90	247.9	54
110	248.5	54
130	249.1	54
160	249.1	54
200	249.1	54
250	249.1	54
300	249.1	54
350	250.2	54
420	250.2	54
540	249.1	54
660	250.2	54
800	253.68	54
1000	252.5	54
1200	253.68	54
1440	253.68	54

ROMALDO COMMUNITY WATER COMPANY

WELL #2

TIME-RESIDUAL DRAWDOWN TEST

RECOVERY

29 June 2017

TIME SINCE PUMP STARTED	TIME SINCE PUMP STOPPED	T/T'	WATER LEVEL
T MIN	T' MIN		FT
1441	1	1441	249.1
1442	2	721	247.9
1443	3	481	247.9
1444	4	361	246.75
1445	5	289	246.75
1447	7	207	246.75
1450	10	145	246.75
1455	15	97	246.75
1460	20	73	246.75
1470	30	49	246.75
1480	40	37	246.75
1490	50	29.8	246.75
1512	72	21	246.75

WELL WATER CHEMICAL DATA

Constituent	Result	Units	Maximum Acceptable
Total Hardness	243	Mg/L	
Calcium	71	Mg/L	
Magnesium	16	Mg/L	
Potassium	ND	Mg/L	
Sodium	26	Mg/L	
Total Cations	6.0	Meq/L	
Boron	ND	Mg/L	
Copper	ND	µg/L	1000
Iron	130	µg/L	300
Manganese	80	µg/L	50
Zinc	40	µg/L	5000
SAR	0.7	--	
Total Alkalinity	190	Mg/L	
Hydroxide	ND	Mg/L	
Carbonate	ND	Mg/L	
Bicarbonate	230	Mg/L	
Sulfate	97.0	Mg/L	500
Chloride	22	Mg/L	500
Nitrate	ND	Mg/L	45
Nitrite	ND	Mg/L	1
Fluoride	ND	Mg/L	2
Total Anions	6.4	Meq/L	
pH	7.5	--	
Specific Conductance	591	µmhos/cm	1600
Total Dissolved Solids	420	Mg/L	1000
MBAS	Negative	Mg/L	0.5
Agressiveness	12.0	--	
Langlier	0.2	--	
Aluminum	30	µg/L	1000
Antimony	ND	µg/L	6
Arsenic	2	µg/L	10
Barium	32.6	µg/L	1000
Beryllium	ND	µg/L	4
Cadmium	ND	µg/L	5
Chromium	10	µg/L	50
Lead	1.6	µg/L	15
Mercury	ND	µg/L	2
Nickel	2	µg/L	100
Selenium	ND	µg/L	50

Silver	ND	µg/L	100
Thallium	ND	µg/L	2
Vanadium	3	µg/L	
Color	ND	--	15
Turbidity	0.9	NTU	5
Odor	ND	TON	3
Chromium VI	ND	µg/L	10

ND = Not Detected